EVOLUTION OF THE RELATIONSHIP BETWEEN PERFORMANCE AND APPROACH RUN VELOCITY IN THE WOMEN'S POLE VAULT

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The purpose of this study was to compare the relationship between approach run velocity and crossbar height for women pole vaulters from 1995 to 1997 and from 1997 to 2003. Videorecords of vaults were used to compute the average interval velocities from 9 to 4 m from the back of the vault box. The average 1997-2003 vault was 0.33 m/s or 4.5% faster and 51 cm or 14.1% higher. Height was significantly correlated to approach run velocity. Linear regression equations predicting height from velocity were computed for each dataset. For a velocity of 8.25 m/s, the regression equations predicted a height 35 cm higher for the 1997-2003 vaults. Improvements in women's vaulting technique have been largely responsible for the increase in vault heights by women between 1995-1997 and 1997-2003.

KEY WORDS: pole vault, women, approach run, velocity, regression.

INTRODUCTION: The first world championship competition in the women's pole vault took place in 1997 at the Sixth IAAF World Indoor Championship and was won at a world record-tying height of 4.40 m. That same year, at the Ninth International Symposium of Biomechanics in Sports, McGinnis (1997) described the relationship between approach run velocity and crossbar height cleared by women pole vaulters and he compared this with the same relationship for men pole vaulters. The relationship was stronger for women and the height predicted from approach run velocity was about one meter lower for women than for men. Seven years later, the world record for the women's pole vault has risen by more than 40 cm and is closer to 5 m than 4 m. Are the improvements in women's pole vault performances due to faster approach run velocities alone, or have techniques improved as well? The purpose of this study was to compare the relationship between approach run velocity and crossbar height for vaults by women pole vaulters in competitions between 1995 and the spring of 1997 with those in competitions between the summer of 1997 and 2003.

METHODS: Shuttered videocameras recorded vaults at eleven different women's pole vault competitions between 1997 and 2003: ten in the United States and one in Canada. A 60 Hz videocamera was used at eight of the competitions and a 240 Hz was used at the other three competitions. At each competition, the camera was positioned 20-60 m to the side of the runway and 5-20 m above the height of the runway. The camera's optical axis was perpendicular to the runway at a point 3-15 m from the back of the box. The shutter speed of the camera varied from competition to competition but was never slower than 0.005 s. The focal length of the camera's zoom lens was adjusted to maximize the image of the vaulter. This generally produced a field of view 3-6 m wide. The camera was panned to follow the approach run and vault by each vaulter. Prior to each competition, visible marks were placed on either side of the pole vault runway at four and nine meters from the back of the vault box.
The videorecords of the vaults were played back field by field on a videocassette player. The time it took a vaulter to move through the five meter interval was determined by counting video fields from the instant the vaulter first crossed the nine meter mark until she crossed the four meter mark. This count was then divided by 60 Hz or 240 Hz as appropriate to determine the time. For the 60 Hz videorecords, if the vaulter crossed the mark between video fields then the count was increased or decreased by 1/2 a field. The precision of the timing was thus 0.0083 s for the 60 Hz videorecords and 0.0042 s for the 240 Hz videorecords. Average horizontal velocity was then computed by dividing the five meter displacement by the computed time. The accuracy of this velocity measurement technique was investigated by McGinnis (1991) who reported relative standard errors of less than 5%. The same technique was used by McGinnis

to measure pole vault approach run velocities in two previous studies (1995, 1997). The single highest successful vault by each subject was chosen for analysis. A correlation and regression analysis was then completed using bar height as the dependent variable and approach run velocity as the independent variable.

RESULTS AND DISCUSSION: Fifty vaulters completed more than seven hundred vaults in the eleven competitions between the spring of 1997 and the summer of 2003. All but 12 of the vaulters were Americans. The non-American vaulters included seven vaulters from Canada, two from Germany, one from Iceland, one from Russia, and one from the Ukraine. Since more than three-quarters of the vaulters were American, the results were considered to describe the characteristics of American women pole vaulters. Only the highest successful vault by each of the 50 vaulters was included in the analysis. The characteristics of these vaults are shown in Table 1 along with characteristics of the vaults from 1995-1997 reported in the earlier study (McGinnis, 1997). Thirty-seven vaulters were included in the earlier study. All but nine of these vaulters were Americans. Six vaulters were included in both sets of data.

Table 1 Vault heights and approach run velocities for women from 1995-1997 (McGinnis, 1997) and from 1997-2003.

		1995-1997	1997-2003
Height (m)	mean	3.48	3.97
	std. dev.	0.33	0.39
	minimum	3.01	2.80
	maximum	4.30	4.70
Velocity (m/s)	mean	7.42	7.75
	std. dev.	0.46	0.44
	minimum	6.58	6.59
	maximum	8.22	8.82
# of vaults	n	37	50

The average approach run velocity for the 1997-2003 vaults was 0.33 m/s or 4.5 % faster than the 1995-1997 vaults, while the average height for the 1997-2003 vaults was 49 cm or 14.1% higher than the 1995-1997 vaults. The faster approach run velocity did not account for all of the increase in performance.

Approach run velocity was linearly correlated to crossbar height. The correlation coefficient was 0.77 ($p < 0.01$) for women's vaults between 1997 and 2003 and 0.82 ($p < 0.01$) for women's vaults between 1995 and 1997. Adamczewski and Perlt (1997) reported a smaller correlation coefficient of 0.59 for vaults by 88 German women between 1991 and 1996. Their approach run velocity was measured measured 1 m further back from the vault box, from 10-5 m from the back of the box rather than 9-4 m from the back of the box. It appears that American women pole vaulters have relied more on speed than technique for their vaulting success when compared with German women vaulters. Data collected by the author for 105 different men pole vaulters between 1986 and 2003 also produced a linear correlation coefficient of 0.77 between approach run velocity and crossbar height.

Linear regression equations which predict crossbar height in meters from approach run velocity in meters per second were produced for the 1997-2003 women's vaults and compared to regression equations based on data from 1995-1997 women's vaults (McGinnis, 1997), 1991-1996 German women's vaults (Adamzcewski & Perlt, 1997), and 1986-2003 men's vaults (data collected by the author). The slopes and intercepts for these linear regression equations are shown in Table 2 along with their correlation coefficients for these four datasets. The vault heights predicted from these regression equations for an approach run velocity of 8.25 m/s are also included in Table 2.

Table 2 Correlation coefficients, the slopes and intercepts of linear regression equations predicting vault height in m from approach run velocity in m/s, and predicted vault heights for a velocity of 8.25 m/s.

	1995-1997 women (McGinnis, 1997)	1997-2003 women	1991-1996 German women (Adamczewski & Perlt, 1997)	1986-2003 men
r	0.82	0.77	0.59	0.77
slope	0.591	0.682	0.684	0.593
intercept	-0.906	-1.304	-1.419	+0.037
std. error est.	0.195	0.252	NA	0.189
Predicted height (m) for 8.25 m/s velocity	3.97 m	4.22 m	4.32 m	4.93 m

For an approach run velocity of 8.25 m/s, a velocity included in all four datasets, the regression equation for 1997-2003 women predicted a height 35 cm higher than the regression equation for the 1995-1997 women but only 10 cm higher than the 1991-1996 German women. Improvements in technique rather than approach run velocity account for this 35 cm increase in performance by the predominantly American group of vaulters. However, it appears that the Americans have improved their technique only slightly better than the technique used by the German women in 1991-1996. The height predicted for the 1997-2003 women is still 61 cm below the height predicted for men. A clearer picture of the relationship between performance and approach run velocity for these four groups of vaulters is shown in Figure 1.

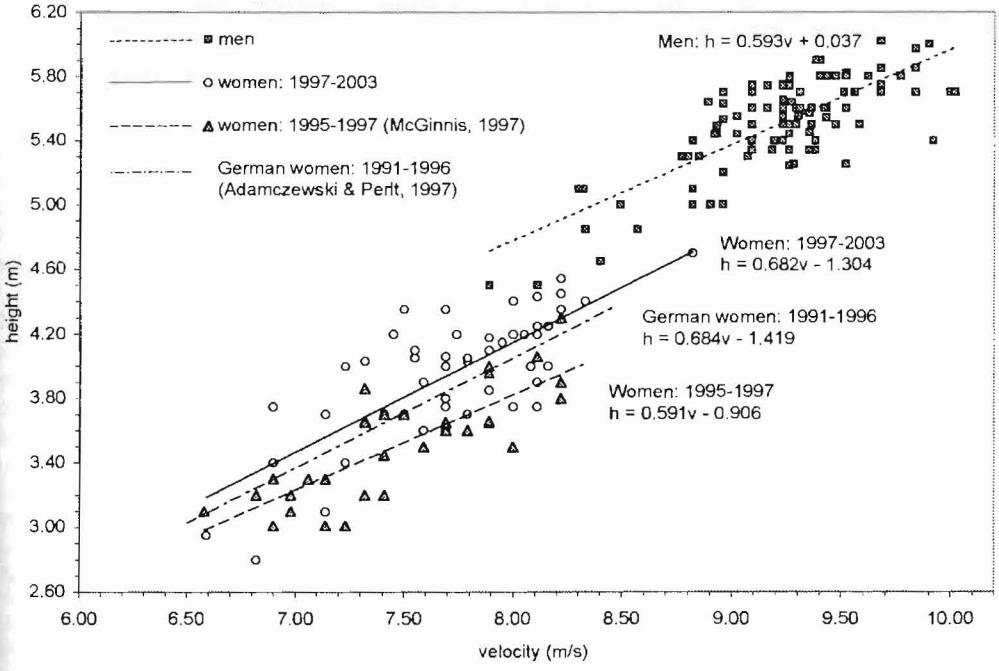

Figure 1: Regression lines and scattergrams of approach run velocity versus crossbar height for vaults by women from 1995-1997, by German women from 1991-1996, by women from 1997-2003, and by men from1986-2003.

CONCLUSIONS: The velocity of the approach run is significantly related to the crossbar height that a pole vaulter can clear. This relationship holds for both men and women pole vaulters as illustrated in Figure 1. It was true for women in 1995-1997 and continued to be true for women in 1997-2003. While approach run velocity is still important, its contribution to performance in the women's vault has decreased. The regression equation for 1995-1997 women's vaults predicted that a woman vaulter would vault about a meter below a man given the same approach run velocity. That performance deficit for the women was narrowed by 35 cm to only 61 cm for 1997-2003 women's vaults. Improvements in women's pole vaulting technique have contributed more to the performance increases in the pole vault during the past seven years than increases in approach run velocity.

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